4.4.3 Aggregate LTE to SATOPS – April 2013

Analysis of Potential Aggregate Long-term Evolution (LTE) RFI to Space-Borne Satellite Operations in 1755-1850 MHz Final Brief

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Department of Defense

Col Harold Martin

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Agenda

- Purpose
- Executive summary
- Interference model
- Analysis results
- Summary and Observations

2163 2

Purpose

- To present analysis and results for predicting aggregate radio frequency interference (RFI) to national security space-borne receivers that would result from commercial LTE network operations in the 1755-1850MHz band
- National Security Space stakeholders concur with analysis methodology, results and conclusions.

2164 3

Executive Summary

- **Examined aggregate Long-Term Evolution LTE interference to satellite operations (SATOPS) receivers in the 1755-1850 MHz band**
  - Analysis is based on CSMAC Working Group 1 (WG1) assumptions about LTE parameters (November 2012 revision)
- **Conclude that there is low risk of interference from aggregate LTE to SATOPS based on current assumptions**
- **Recommend establishment of rules/regulations capturing a threshold of -205 dBW/Hz for aggregate LTE emissions to ensure continued protection of satellite receivers**

Model predicts minimal impact to national security spacecraft from LTE

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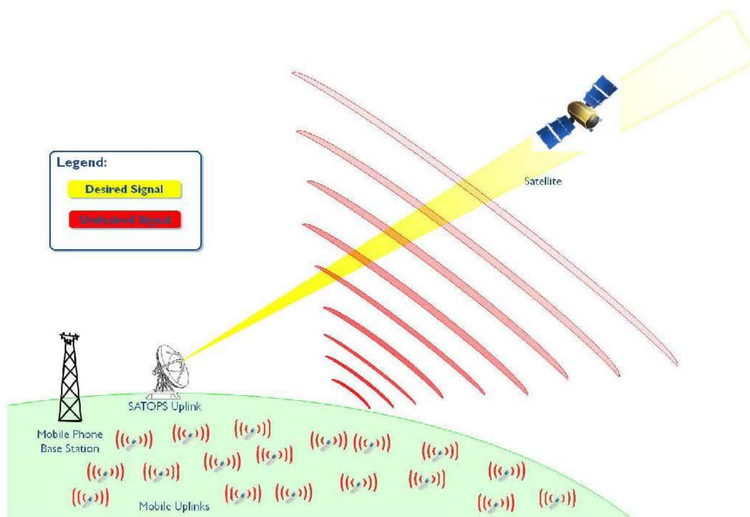
Purpose of Model



This analysis examines interference from LTE handset transmissions only

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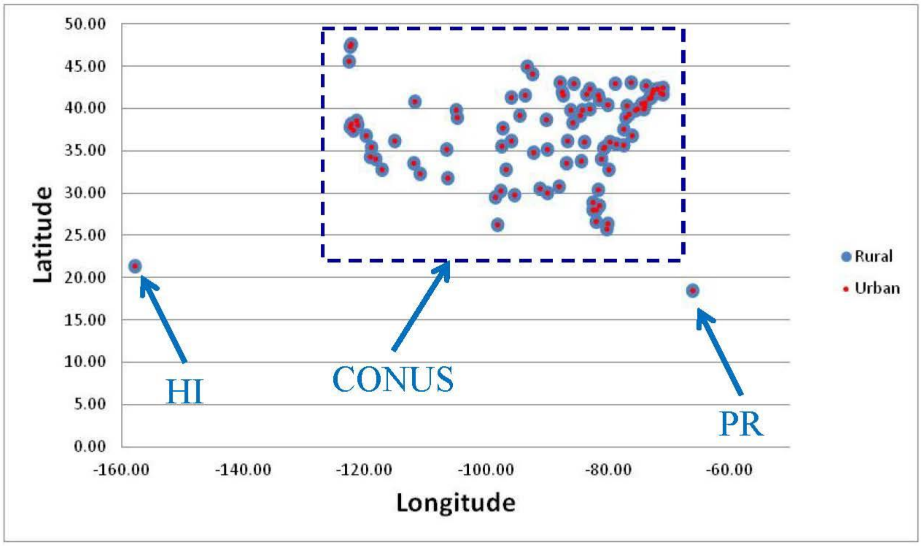
CSMAC WG1 "Grid Model" Method



LTE network modeled as urban and rural base stations in top 100 cellular U.S. market areas

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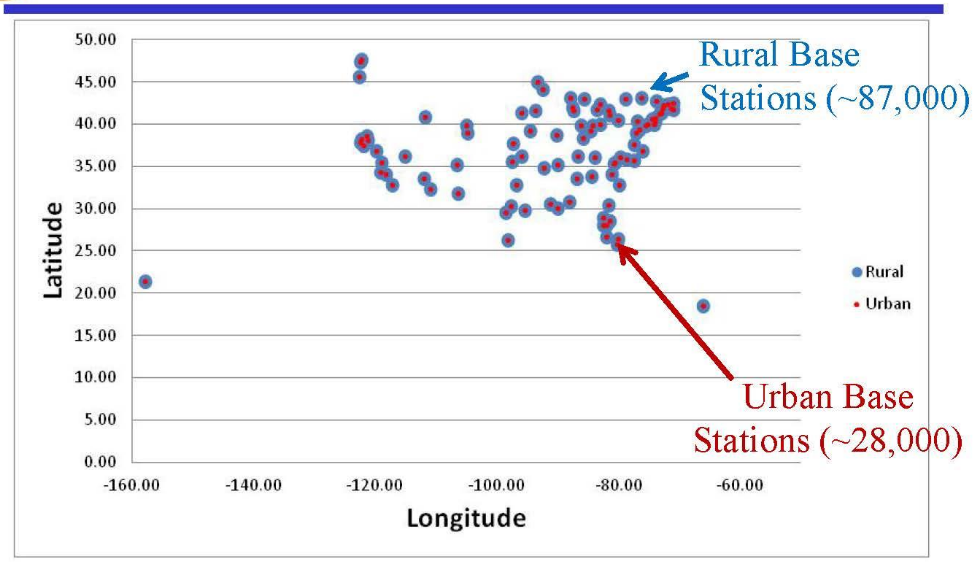
CSMAC WG1 "Grid Model" Method



LTE network modeled as urban and rural base stations in top 100 cellular U.S. market areas

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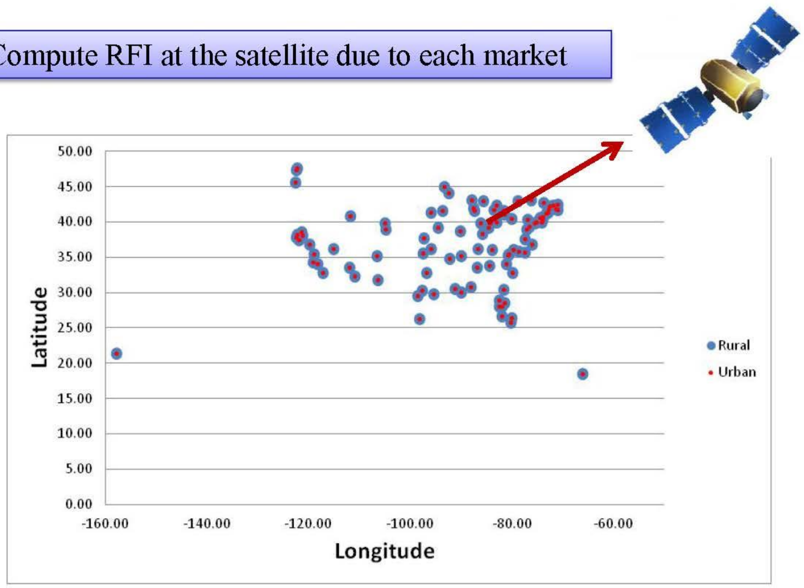
CSMAC WG1 "Grid Model" Cont.

Compute RFI at the satellite due to each market



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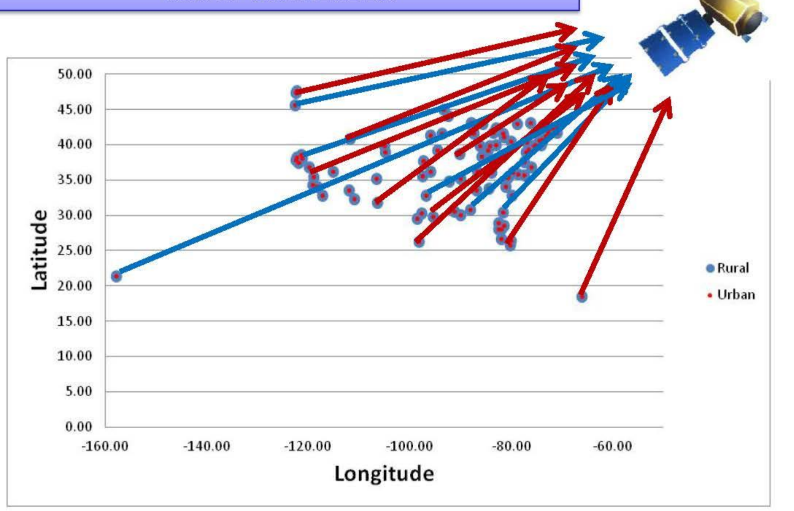
CSMAC WG1 "Grid Model" Cont.

Total RFI at the satellite is the sum of the RFI due to each market



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Analysis Results by Program

- **Most major Air Force and Navy programs analyzed**
- **-205 dBW/Hz determined to be a safe RFI level at geostationary orbit for most programs**
  - Derived from requirements documentation of all programs
  - Also ensures a safe level of RFI for most low earth orbit programs
  - Receiver designs/technology not expected to change significantly
  - A few experimental programs may not be protected by this level
- **Aggregate mean RFI is estimated by the model to be -212.6 dBW/Hz (7.6 dB below the safe level), but additional consideration is needed for the experimental programs, e.g., during transition planning**
- **Insignificant RFI variation due to LTE power control (σ = 0.12 dB)**

Negligible RFI to all programs except possibly a few experimental spacecraft

2171 10

Additional Factors

- **L-band would only hold a fraction of total cell phones in the US**
  - 1755-1850 is ~20% of total cellular spectrum, 1755-1780 ~5%
  - Per CSMAC WG1 parameters, planned LTE architecture would support ~1.8 million simultaneous UE transmitters in view of GEO per 10 MHz
- **Time variations in network use**
  - Network loading mid-day >> midnight
  - Modeling assumed all base stations operating at capacity
- **Line-of-sight obstructions**
  - Modeling assumes all UEs have line-of-sight to the satellite
- **Time for commercial to build-out their network in the band**
- **Spacecraft thresholds often based on most stressing case**
- **Future use of the band could be much different than current LTE plans (e.g., machine-to-machine, etc. applications)**

Practical RFI occurrences may be less than modeled/worst case

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Summary and Observations

- There is low risk of interference from aggregate LTE to SATOPS based on current assumptions
- Establishment of rules/regulations defining a threshold of -205 dBW/Hz for aggregate LTE emissions would ensure continued protection of satellite receivers

References

- CSMAC Working Group #1 “Baseline LTE Uplink Characteristics” 12 November 2012 – Rev.2
- Yeh, J. P., “IMT-2000 study” Aerospace Report No. TOR-2002(8584)-1, 15 December 2001

Backup

Analysis Inputs (1/2)

Parameter	Description	Value	Source
Spacecraft sensitivity	Determines impact of RFI; computed at air interface to the receive antenna	By program	Program spec
Spacecraft position	Altitude of spacecraft	By program	Program spec
Frequency	Spacecraft receiver center frequency	By program	Program spec
LTE Gain	Transmit antenna gain of LTE User Equipment (UE) towards spacecraft	-3 dBi	CSMAC WG1
UEs/base station	# of UEs per base station	18	CSMAC WG1
LTE BW	Bandwidth of LTE network	10 MHz	CSMAC WG1
Loading	LTE network usage relative to max capacity	100%	CSMAC WG1

15

Analysis Inputs (2/2)

Parameter	Description	Value	Source
Rural Cell Radius	Distance from base station to cell edge in rural areas	3.5 km	CSMAC WG1
Urban Cell Radius	Distance from base station to cell edge in urban areas	0.867 km	CSMAC WG1
Rural UE Power	Mean transmit power for UEs in rural cells	13.44 dBm	CSMAC WG1
Urban UE Power	Mean transmit power for UEs in urban cells	5.53 dBm	CSMAC WG1
Rural UE Variance	Statistical variance of rural UE transmit power due to power control	817.34 mW^2	CSMAC WG1
Urban UE Variance	Statistical variance of urban UE transmit power due to power control	104.52 mW^2	CSMAC WG1

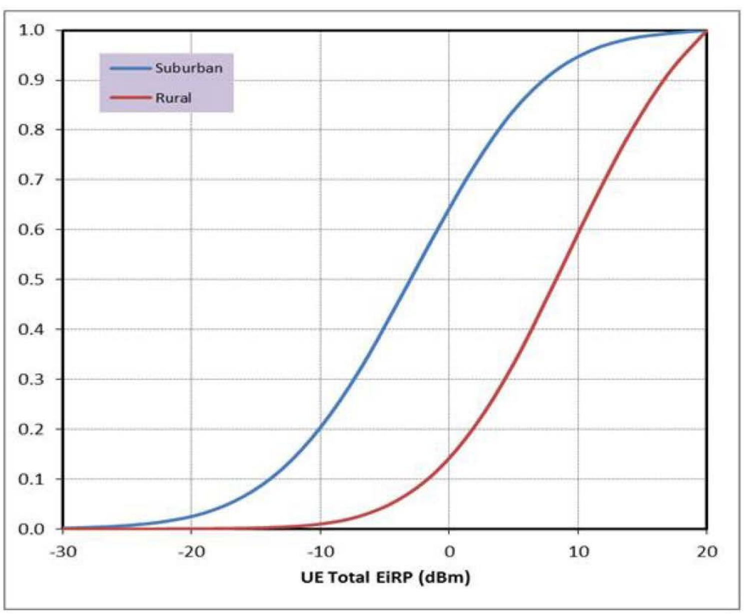
Detailed Input Descriptions (1/2)

- **Spacecraft sensitivity is the threshold interference power density incident at the spacecraft antenna that would be considered harmful. This sensitivity is computed for each program based on link requirements contained in relevant interface documentation. The threshold represents the amount of additive thermal noise power that would result in 0 dB margin for link closure at the required error rate.**
- **Spacecraft position is handled parametrically. Only spacecraft altitude is entered into the model. Interference power is then computed for all possible locations of the spacecraft through its orbit and the worst-case value is returned.**
- **LTE gain describes the nominal gain of all LTE transmitters towards the spacecraft. LTE handsets, also known as user equipment (UEs), are assumed to have an omni-directional antenna pattern.**
- **UEs/base station describes how many UEs are transmitting within any given cell which is covered by a single base station. The value provided by CSMAC WG1, 18, represents the maximum number of simultaneously transmitting UEs per base station in a 10 MHz bandwidth network.**
- **LTE BW is the assumed bandwidth of the LTE network. For the purposes of this analysis, the modeling assumes a 10 MHz network is deployed across the U.S. co-channel with every DoD spacecraft in the 1755-1850 MHz band.**

Detailed Input Descriptions (1/2)

- Loading represents the usage of the network relative to capacity. A value of 100% means the network is operating at capacity and could not support one additional subscriber anywhere in the U.S. In reality, LTE networks are never operating at 100% capacity, and even individual cells in high traffic areas only operate near capacity on occasion.
- Rural/Urban cell radius describes the coverage area of each individual base station. This value is used to determine how many base stations (and thus how many UEs) are operating in a given land area. Note that cell radii take on one of two values depending on whether the cell is in an area considered to be urban or rural.
- Rural/Urban UE power provides the mean/average transmitter power of LTE handsets, depending on whether the handset is in a rural or urban area. Rural cells generally cover larger areas, so UEs operate on average with higher power to cover larger distances.
- Rural/Urban UE variance provides a statistical metric for the variation of LTE handset transmitter power due to power control of the handsets. Both the mean and variance terms are derived from UE transmit power distributions provided by CSMAC WG1. UEs operate over a wide range of power levels (from -30 dBm to +20 dBm), thus the values for variance are large relative to the mean.

UE Power Control Distribution



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Assumptions

- Victim satellite assumed to receive interference with constant antenna gain over US
- Mobile stations assumed to transmit with omni antenna gain
- Wireless network deployed over United States using coverage of circular area around top 100 US cities identified by CSMAC WG #1
- Transmitters in the network are dispersed evenly over the total network bandwidth such that aggregate transmitter power results in an even power density across the network band.
- Interference power at the victim satellite is assumed to be the linear sum of powers contributed from the multitude of network transmitters
- Interference powers follow line-of-sight free space propagation
- Atmospheric loss is assumed, given by 0.9394*exp(-0.077*X), where X is the elevation angle from the transmitter to the victim satellite. This is consistent with the 2001 version of the Aerospace model.
- Interference is computed as link budgets from the center of each of the 100 identified major commercial market areas. A circle of land centered at the latitude and longitude of the market area with a radius of 30 km is assumed to be covered with suburban cells. A surrounding ring of land with an inner radius of 30 km and outer radius of 100 km is assumed to be covered by rural cells. Interference from all transmitters in the suburban and rural cells is calculated as though it originates from the center of the region. Range and pointing angle/antenna gain to the victim satellite is considered from each region center. Regions that have an elevation angle to the victim satellite less than zero will not be counted as a contributor of interference power.

2181 20

Standard Deviation Calculation

- **Key properties:**

$$\mathrm{Var}(x) = \sigma_x^2 = \mathrm{E}\left\{(\mathrm{x} - \mu_\mathrm{x})^2\right\}$$

-Definition of variance and standard deviation

$$\mathrm{Var}\left(\sum_{i=1}^{n} a_i x_i\right) = \sum_{i=1}^{n} a_i^2 \,\mathrm{var}(x_i)$$

$$\mathrm{E}\left(\sum_{i=1}^{n} a_i x_i\right) = \sum_{i=1}^{n} a_i \, E(x_i) = \mu_x \sum_{i=1}^{n} a_i$$

-Total RFI variance and mean can be computed in terms of the sum of the variances and means of the individual handsets (x_i are independent and identically distributed)

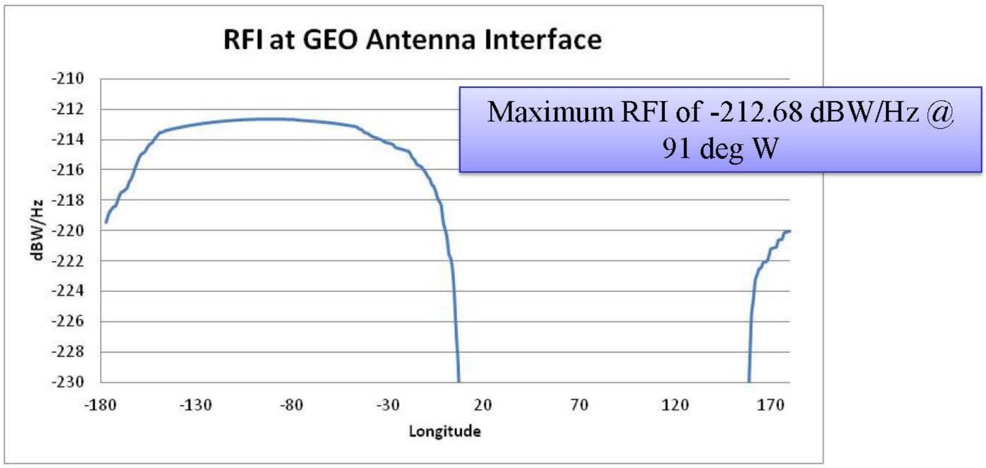
$$\sum_{i=1}^{n} x_i \sim N(n\mu_x, n\sigma_x^2)$$

-Total RFI is approximately normally distributed and defined by the variance and mean per the Central Limit Theorem (for sufficiently large number of transmitters)

2182 21

RFI at GEO

- RFI vs. geostationary longitude at 1800 MHz frequency
- Cellular distribution per CSMAC WG1 “grid model”



22

4.4.4 Government Satellite Control – Second Submittal – May 2013

CSMAC WG3 Government Satellite Control – Second Submittal

May 2013

Col Harold Martin

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Office of Security Review
Department of Defense

13-S-2116

Outline

- Purpose of Submittal
- Government Ground Stations
- Additional AFSCN Information
- Site Usage
- Aggregate Mobile Wireless RFI to Government Uplinks
- Sharing
- Remarks

2188 2

Purpose of Briefing

- This briefing is a second submittal of information regarding Government satellite control (SATOPS) uplinks that are produced by various stations in US&P in the 1755 – 1850 MHz band (L-band)
- The primary content of this second submittal is the additional listing of some government ground stations uplinking in L-band. This submittal also addresses a few minor industry questions and corrects a few items that were incorrect in the first submittal.
- Some items are repeated from the first submittal for clarity only

2189 3

Basic Concept

- This data is a reasonably accurate engineering summary response to industry questions and business decision needs
- The intent is to satisfy these basic industry needs without violating Government sensitivity/classification requirements
- This is <u>only</u> a snapshot of the present and near future SATOPS L-band use
- This data <u>will</u> change in the future
- Final policy decisions will be made through the Policy and Plans Steering Group (PPSG), and implemented in accordance with NTIA and OMB procedures and Federal law, including transition plan, cost reimbursement, and comparable spectrum.

This only defines the general scope

4

Government Tracking Stations (1/2)

AFSCN

- Vandenberg Tracking Station, Vandenberg AFB, California (VTS)
- New Hampshire Tracking Station, New Boston AFS, New Hampshire (NHS)
- Thule Tracking Station, Thule Air Base, Greenland (TTS)
- Guam Tracking Station, Andersen AFB, Guam (GTS)
- Hawaii Tracking Station, Kaena Point, Oahu, Hawaii (HTS)
- Colorado Tracking Station, Schriever AFB, Colorado (CTS)
- Oakhanger Telemetry and Command Station, Borden, Hampshire, England (TCS)
- Diego Garcia Tracking Station, British Indian Ocean Territory, Diego Garcia (DGS)
- Eastern Vehicle Checkout Facility, Cape Canaveral AFS, Florida (EVCF) (Launch support only)

Navy Facilities

- Prospect Harbor, Maine (Navy) (PH, ME)
- Laguna Peak, California (Navy) (LP, CA)
- Blossom Point, Maryland (BP, MD)
- *NAVSOC Det. Charlie (Navy) (GNS)*

Stations shown in italics are additions to those listed in the first Government submittal

5

Government Tracking Stations (2/2)

Other Facilities

- Buckley AFB, Colorado (BAFB)
- Fairbanks (NOAA), Alaska (FB, AK)
- Kirtland AFB, New Mexico (KAFB)
- Fort Belvoir, Virginia (FB, VA)
- Camp Parks, California (CP, CA)
- *Annapolis, Maryland (AN, MD)*
- *Monterey, California (MO, CA)*
- *Cape GA, CCAFB, Florida (CAPEG)*
- *Huntington Beach, CA (HB, CA)*
- *Joint Base Lewis-McChord, WA (JB, WA)*
- *Ft Hood, TX (FH, TX)*
- *Ft Bragg, NC (FB, NC)*
- *JIATF-S, Key West, FL (KW, FL)*
- *Patuxent River NAS, MD (PR, MD)*
- *Sacramento, CA (SAC, CA)*

Stations shown in italics are additions to those listed in the first Government submittal

2192 6

General DoD Site Information

- **Antenna patterns follow classical parabolic characteristics**
- **All sites adhere to NTIA Manual 5.6.2 that limits all SATOPS radiation to 3 degrees elevation or higher**
- **All sites transmit over a 360 degrees azimuth as needed**
- **All sites listed only are used for uplink radiation in L-band**
- **For sites with multiple antennas, the percentage of radiation from at least one antenna as averaged over a year is presented in a later chart**
- **For sites with multiple antennas, only the maximum gain and power of the largest antenna is given**
- **The smallest to maximum mission bandwidths are given. Actual bandwidth used is dependent upon precise mission operations. Of course zero radiation and bandwidth occurs some of the time.**
- **Percentage of GEO spacecraft support and percentage of supports in the 1755 – 1780 MHz band are provided for each site**

2193 7

General Operational Information

- **Approximately 90% of all SATOPS L-band radiation in US&P is done by four major AFSCN sites**
  - NHS, VTS, HTS, GTS
  - Only one spacecraft supported for each antenna for any given time (typically 2 antennas/site)
  - All AFSCN sites support all channels and have same basic configurations
- **AFSCN supports more than 150 spacecraft**
  - LEOs, MEOs, and GEOs are supported as required with no preset order
  - ~40% of all spacecraft are GEOs
  - ~17% of the total spacecraft are in 1755 – 1780 MHz band
  - About 45% of all spacecrafts have multiple frequencies in L-band
  - About 40% have additional bands which are not suitable for SATOPS assured access
  - Approximately 3% are configured for 2025 – 2110 MHz operations
- **AFSCN traditionally has used 20 channels with 4 MHz width – vast majority of spacecrafts on-orbit are in this configuration**
  - Now uses 440 channels with 160 kHz separation – current practice is to have new spacecrafts transponder assignments conformed to this convention. Remote tracking stations are also being updated.
  - Several modulation formats are used (1 kilosymbol commands plus ranging is most common)
  - Spacecrafts have been assigned frequencies with this new bandwidth for the last 5 years
  - Power varies from 500 W (4%), 1000 W (95%), 2250 W (1%), 7244 W (0.1%)
  - High power used only for anomalies
- **Anomalies (~ 1%) require maximum SATOPS support using similar RTS actions**

Chart unchanged – provided for informational purposes only

2194 8

Aggregate RFI to SATOPS Uplinks

- **Aggregate RFI from 4G LTE mobile wireless to SATOPS appears acceptable based on prior studies and the assumption of indicated mobile handset users equipment (UE) power control**
- **2001 studies by JSC mobile wireless IWG and Aerospace**
  - 20 dB difference in results
  - JSC and Aerospace concluded near zero (+/- 6 dB) SATOPS command link margins due to cellular downlink
- **2010 analysis update**
  - Cellular uplink: some stressing cases with near zero command margin assuming 23 dBm uplinks
- **Previous studies did not include power control**
  - WG1 reported ~5 dBm average power for LTE cellular uplink case
  - Use of ~5 dBm UE Tx power in modeling results in ~20 dB less interference thus negligible reduction in SATOPS link margin
  - Higher UE powers could change this result

This subject is under further Government wide review

Sharing agreement should require further coordination for any significant departure from planned 4G/LTE architectures (e.g., higher Tx transmitter and/or UE densities power)

2195 9

US&P Government Site List (1/2)

Gov't Sites	Latitude	Longitude	Elevation above MSL (m)	Max Transmitter Power (dBW)	Max Antenna Gain (dB)	*Radiation Time (%)*	Auth Spectrum Use (MHz)	*Instantaneous Spectrum Use Max (MHz)*	*% Spacecraft 1755-1780 MHz*	% GEO Support
VTS	34-49-22.8N	120-30-7.2W	269	37.1	45	*65*	81	*0.2 - 6*	*17*	40
NHS	42-56-45.6N	71-37-44.4W	200	38.6	45	*60*	81	*0.2 - 6*	*17*	40
GTS	13-36-54N	144-51-21.6E	218	37.1	45.1	*100*	81	*0.2 - 20*	*17*	40
HTS	21-33-43-2N	158-14-31.2W	430	32.1	45.4	*70*	81	*0.2 - 5*	*17*	40
CTS	38-48-21.6N	104-31-40.8W	1910	31.2	45	*30*	81	*0.2 - 4*	*17*	40
EVCF	28-29-09N	080-34-33W	*2*	23	28	*< 1*	81	*0.2 - 4*	*17*	40
PH, ME	44-24-16N	068-00-46W	*6*	31	38	*3*	81	*3*	*0*	100
LP, CA	34-06-31N	119-03-53W	*439*	31	43	*9*	81	*3*	*0*	100
GNS	*13-34-57.6N*	*144-50-36.1E*	*208*	*15*	*40*	*9*	*81*	*2*	*0*	*100*
BP, MD	38-25-53.5N	77-05-06.4W	19	25	46	*45*	81	*0.2-5*	*80*	0

Items shown in italics are additions/changes to those listed in the first Government submittal

10

US&P Government Site List (2/2)

Gov't Sites	Latitude	Longitude	Elevation above MSL (m)	Max Transmitter Power (dBW)	Max Antenna Gain (dB)	*Radiation Time (%)*	Auth Spectrum Use (MHz)	*Instantaneous Spectrum Use Max (MHz)*	*% Spacecraft 1755-1780 MHz*	*% GEO Support*
BAFB	39-42-55N	104-46-29W	*1726*	32	43	*18*	81	*2*	*0*	*100*
FB, AK	*64-58-49N*	*147-31-5W*	*331.1*	20	43	*11*	81	*2*	*0*	*0*
KAFB	34-59-46N	106-30-28W	*1600*	28	38.4	*0.6*	81	*2*	*67*	*0*
FB, VA	*38-44-04N*	*077-09-12.5W*	*61*	25	*40*	20	*81*	*4*	*0*	*50*
CP, CA	37-43-51N	121-52-50W	*300*	30	42	*Not Currently Operational*	81	-	-	-
AN, MD	*38-58-60N*	*76-28-60W*	*24*	*14.8*	*36*	*4*	*81*	*2*	*100*	*0*
MO,CA	*36-35-42N*	*121-52-28W*	*102*	*14.8*	*36*	*4*	*81*	*2*	*100*	*0*
CAPEG	*28-29-03N*	*80-34-21W*	*6*	*24*	*40*	*46*	*81*	*2*	*0*	*0*
HB, CA	*33-44-49.8948N*	*118-2-3.84W*	*11*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*
JB, WA	*47-06-11N*	*122-33-11W*	*86*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*
FH, TX	*31-08-57N*	*97-46-12W*	*300*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*
FB, NC	*35-09-04N*	*78-59-13W*	*89*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*
KW, FL	*24-32-36N*	*81-48-17W*	*2*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*
PR, MD	*36-16-28N*	*76-24-45W*	*6*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*
SAC, CA	*38-39-59N*	*121-23-33W*	*23*	*24*	*26.8*	*2*	*81*	*1*	*0*	*0*

Items shown in italics are additions/changes to those listed in the first Government submittal

11

Remarks

- **US Government has many critical SATOPS uplinks in 1755-1850 MHz from limited fixed worldwide locations**
  - 4 US&P AFSCN sites are heavy hitters
  - Spacecraft have long lives and frequencies are fixed during design
- **Final policy decisions will be made through the Policy and Plans Steering Group (PPSG), and implemented in accordance with NTIA and OMB procedures and Federal law, including transition plan, cost reimbursement, and comparable spectrum.**
- **Cooperative Government/Industry analyses/tests needed to assess possible sharing solutions**
  - Tests are highly desired
- **Government needs Industry input regarding what is desired next**
- **National security issues are a key factor**
- **Regulatory provisions must allow for Government growth including the possibility of more use at existing sites and coordination of new sites**

Sharing solutions must be enduring

2198 12

Backups

- **The following charts are graphical depictions of North America as viewed from a typical spacecraft with a omni directional field of view as depicted by the white circle on the following charts**
- **New Hampshire Tracking Station (NHS) is shown FYI only**
- **Plots 1-3 are for a satellite (locations indicated) with a 50 degree inclination and a 650 km circular altitude with the orbit depicted by the purple line on the following charts**
- **Plot 4 is for a geosynchronous satellite at 102 W longitude**
- **This material is included to satisfy an industry question only**
- **This does NOT refer to any actual Government spacecraft, it is presented for information only**
- **This information is commonly known in the public record**

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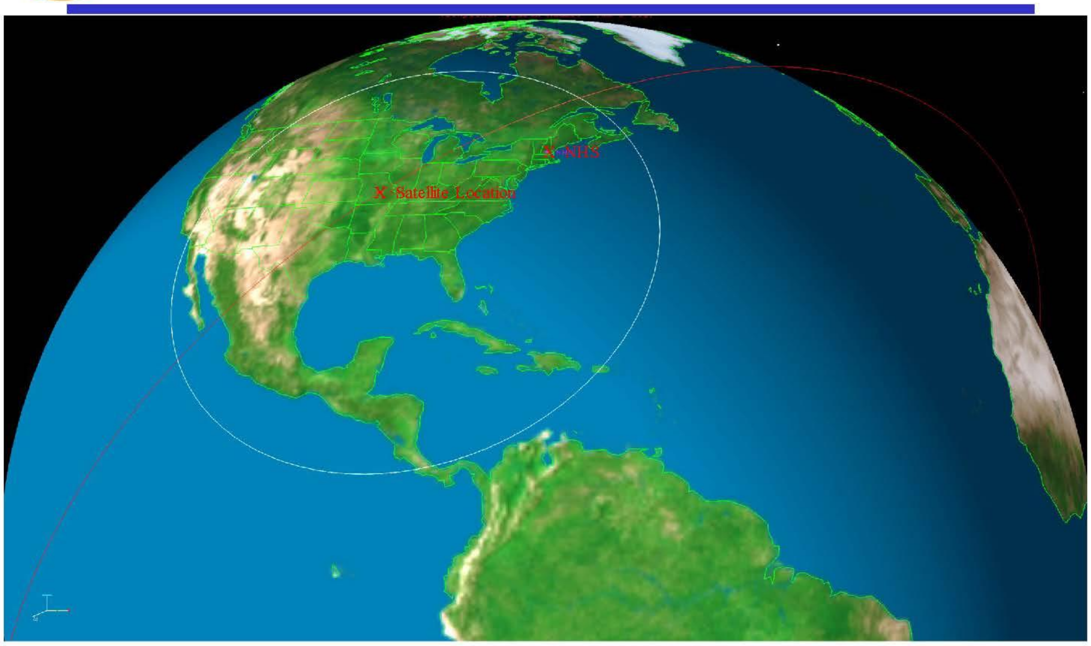
Plot 1 Satellite over mid US



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Plot 2 Satellite over North Atlantic

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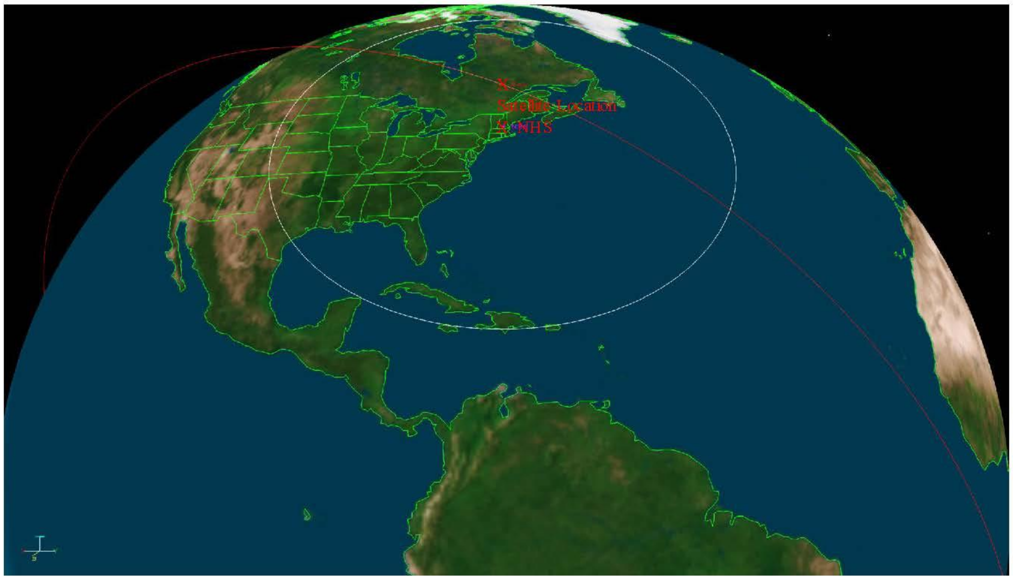
Plot 3 Satellite over Canada



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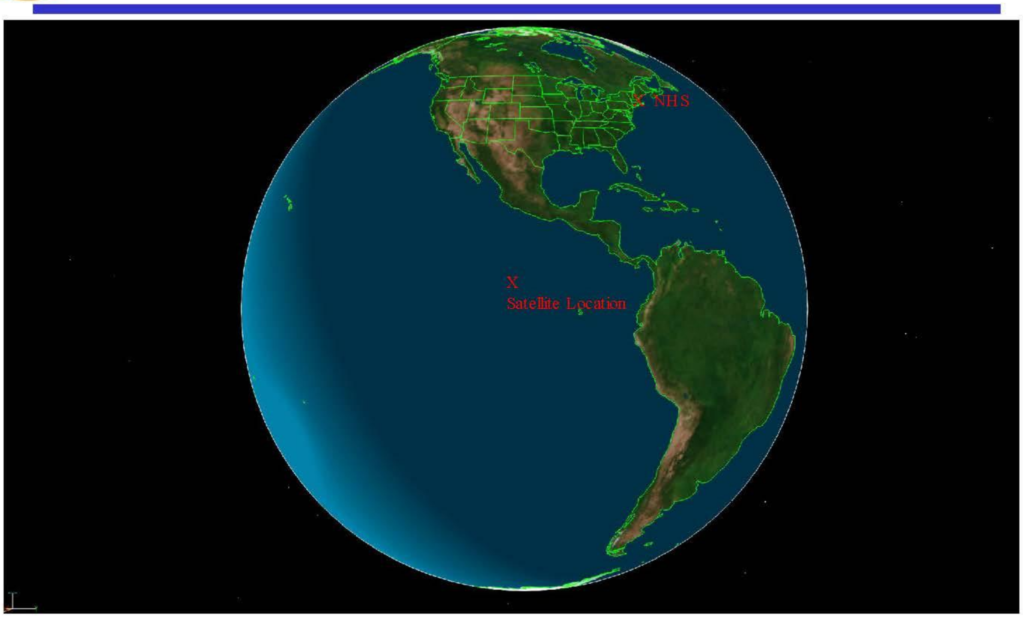
Plot 4 GEO Satellite at 102 W Longitude



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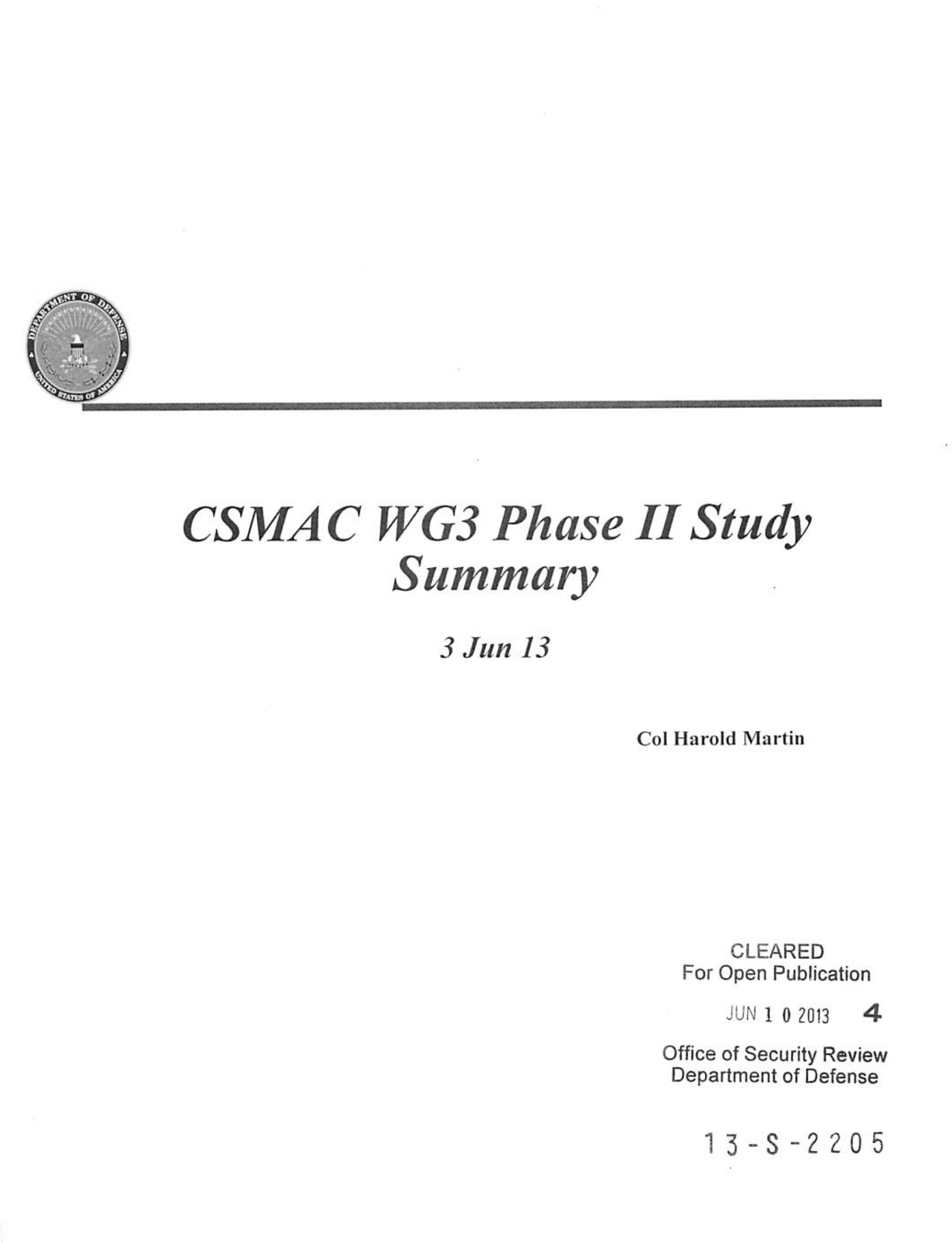
4.4.5 Phase 2 Study Summary – June 2013

"Commerce Spectrum Management Advisory Committee (CSMAC) Working Group (WG) 3 Phase II Study Summary", June 3, 2013. The charts in this section were reprinted with permission of the Aerospace Corporation.



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Technical Report

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Forward

The concepts and analysis provided in this report are intended for Government and Commerce Spectrum Management Advisory Committee (CSMAC) discussion purposes only

The information is provided for use in developing estimates only and is not intended to be representative of actual ground site operating parameters in the future

Government operational information for the 1755-1850 MHz band studied in this report has been summarized and enveloped to avoid presenting individual program or ground site information

3

Outline

- **Executive Overview**
- **Purpose**
- **Methodology**
- **Results**
- **Summary**
- **References**
- **Appendix**
  - *A. Study Results*
  - *B. Technical Rationale*

2212

Executive Overview

The Department of Commerce National Telecommunications and Information Administration (NTIA) identified the Commerce Spectrum Management Advisory Committee (CSMAC), as the primary forum to facilitate technical discussions between industry and federal agencies regarding repurposing spectrum for commercial use. CSMAC Working Group 3 is focused on sharing of the 1755-1850 MHz band between federal satellite operations (SATOPS) , DoD electronic warfare and commercial mobile wireless (MW) broadband. CSMAC Working Group 3 and the DoD Chief Information Officer (DoD/CIO) requested a characterization of Government satellite operations at specific ground stations that could potentially impact commercial MW broadband operations in the future.

Government uplink emissions were analyzed from three Air Force Satellite Control Network sites (New Hampshire Station, Vandenberg Tracking Station, Hawaii Tracking Station), two Navy sites (Blossom Point and Laguna Peak Tracking Station) and the NOAA Fairbanks Alaska site. The analyses made use of NTIA's Irregular Terrain Model (ITM) associated with the NOAA/NGDC GLOBE terrain database for propagation prediction in conjunction with historical SATOPS information. The results are presented on maps in the vicinity of the selected SATOPS locations to display, as a function of distance and azimuth from the SATOPS sites, contours of two parameters: 1) the predicted peak received power levels (for median value of path loss), and 2) the probability over time that the received power does not exceed the selected MW interference threshold.

The results of modeling transmitted radiation as a function of distance from each site, with various attenuation scenarios are presented. Potential exceedence of the standard LTE threshold is also presented for each case. In addition, estimates of site usage based on satellite contact parameters are provided. The presentation format for the simulation outputs was specified by CSMAC Working Group 3. Uncertainties associated with each of the models used (mission astrodynamics, power, path loss, terrain, and probabilities) are described, including propagation variabilities and approximations of the terrain data. The models have inherent limitations such as lack of vegetation information, so the data should not be construed to be actual power levels of the AFSCN or other sites.

In summary, this report provides estimates of the areas potentially impacted by Government radio emissions from selected ground facilities. The information is provided for estimating purposes only and is not intended to be representative of actual ground site operating parameters in the future.

2213

Purpose

- The purpose of this study is to provide a characterization of Air Force, Navy and NOAA uplink Satellite Operations (SATOPS) in the band 1755-1850 MHz and to estimate areas in the vicinity of Government ground sites that are potentially subject to interference
- The intended use of this study is for transmittal to the CSMAC WG3
- Info should be used for determining the next steps of evaluation and not for final decisions regarding spectrum sharing within bands

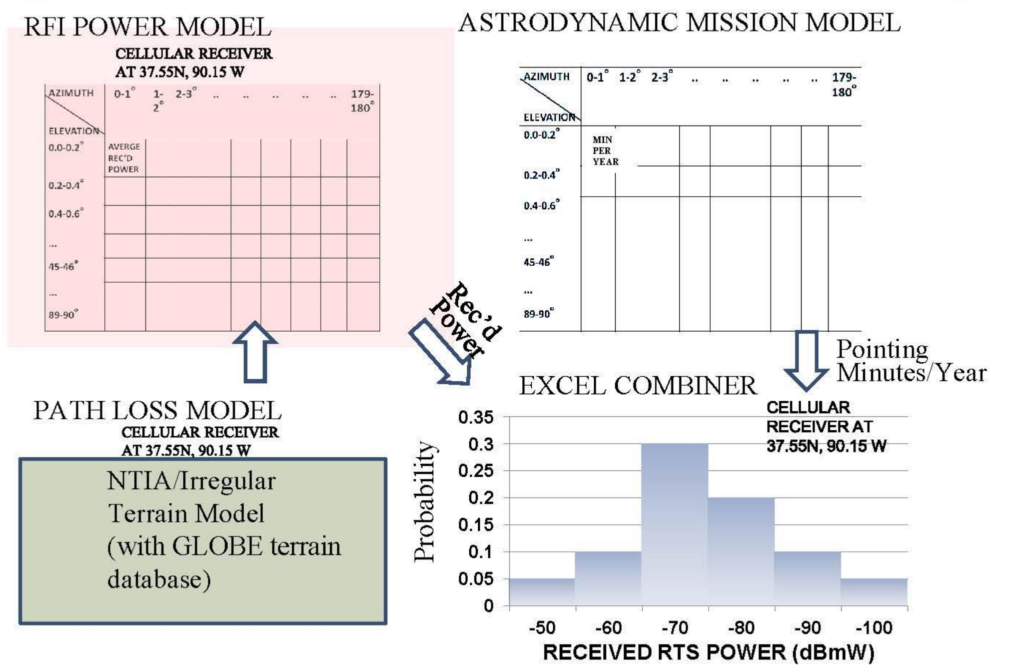
2214

Methodology

- **Computer Tools Used in Study**
  - *The Power Model is a specialized scenario using the Aerospace SOAP Model (Ref. 1) that computes Radio Frequency Interference (RFI) power received by a cellular base station (receiver) when a SATOPS antenna is pointed in each Azimuth/Elevation (Az/El) cell*
  - *The Path Loss Model computes RFI reduction at a cellular base station (receiver) as input to the Power Model. This computation uses the NTIA Irregular Terrain Model (Ref. 2) with the GLOBE Terrain Data Base (Ref.3).*
  - *The Aerospace Astrodynamics Mission Model computes, for each SATOPS site, the transmit minutes per year (average) in each Az/El cell*
  - *The EXCEL Combiner Model computes, for a cellular base station (receiver), a RFI power histogram and the "probability" of RFI power not exceeding the receiver threshold of harmful interference*
- **The accompanying chart shows the four major computer tools used in this study, and the data flows between them**

2215

Methodology - Calculating Base Station Received Interference (resulting from given Government SATOPS antenna)



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Methodology - Propagation Models

- **No single propagation model is best suited for all purposes**
  - *Some models are conservative regarding predicting interference (i.e., lead to predicting more interference than would really occur)*
  - *Other models are conservative towards identifying low signal levels (i.e., lead to predicting lower received power than would really occur)*
- **Models also have varying degrees of accuracy**
- **While there are varying degrees of uncertainty associated with any model, these types of models are typically applied in spectrum management studies**

2217 9

Methodology - Theoretical Bases and Assumptions (1/3)

- **Path Loss**
  - *Each path loss is the median value loss computed by the Irregular Terrain Model (the NTIA path loss model adopted by CSMAC) using the "Globe Database" of terrain elevation maps*
- **Pointing Minutes**
  - *Output of Aerospace Astrodynamic "Mission Model" orbital simulation for each SATOPS site*
  - *The minutes of radiate time is the sum of the contributions of all satellites in the "Mission Model" in the spectral band of interest that operate in the band of interest, distributed over all Az/El cells above minimum allowable elevation angle*
  - *Radiate time amounts to a fraction of the total contact time*
  - *Contact start and end times are derived from recorded experience*
  - *Radiate start time is randomly distributed uniformly over contact time*

2218

10

Methodology - Theoretical Bases and Assumptions (2/3)

- **Received power histogram for antenna sites**
  - *For single antenna sites, at each power level, the "probability" is defined as the sum of the "Mission Model" Az/El cell values (which are the annual transmit minutes for each Az/El) divided by yearly minutes for all the same Az/El cells corresponding to the received power level*
  - *For sites with 2 or more antennas, "probability" is defined as percent time (all site antennas) below threshold RFI level, less percent time of overlap (i.e. simultaneous radiation)*
- **Threshold Exceedance Contours**
  - *The probability that the RFI doesn't exceed threshold power level, assuming that the path loss is, in fact, the median value given by the ITM model (see Model Limitations)*
  - *Is the complement of the sum of probabilities for received power levels exceeding the threshold level*
  - *The "LTE Threshold" is assumed to be -137.37 dBW or (-107.37 dBm) using CSMAC WG-1 documented values (Ref. 4)*

2219

11